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Evaluation of aerodynamic forces acting on oscillating cantilever beams based on the study of the damped flexural vibration of aluminium test samples

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ABSTRACT

The paper is devoted to study of the aerodynamic forces acting on flat cantilever beams performing flexural vibrations in a viscous fluid. Original method for the force evaluation is presented based on analysis of experimental measurements of a logarithmic decrement of vibrations and relative variation in frequency of duralumin test specimens. The theoretical core of the method is based on the classical theory of bending beam oscillations and quasi-two dimensional model of interaction between a beam and a gas. Using the proposed method, extensive series of experiments for a wide range of oscillations parameters were carried out. The processing of the experimental data allowed to establish the global influence of the aerodynamic effects on beam oscillations and the local force characteristics of each cross-section of the beam in the form of universal functions of dimensionless amplitude and dimensionless frequency of oscillation. The obtained estimates of the drag and added mass forces showed a good correspondence with the available numerical and experimental data practically in the entire range of the investigated parameters.

1. Introduction

The past few decades have witnessed a risi interest in the study of mechanical vibrations of the beams in viscous static fluids. The motivations for these studies stem from different practical applications covering diverse fields of knowledge such as atomic microscopy [1], sensors and actuators based on micromechanical oscillators [2], cooling devices [3], actuators of underwater robotic devices [4,5], marine and offshore equipments [6,7]. Our interest in this research area is connected with the development of the approach [8,9] for determination of the damping properties of materials based on the study of the damped flexural vibration of cantilever flat test samples.

In the general, the problem of evaluation of aerodynamic forces acting on a cantilever beam is extremely complicated, mainly because of the complexity of three-dimensional gas flows caused by vibrations of the beam. But in the case when the length L of the beam considerably exceeds its width b and thickness h, at low structural vibration modes the length of the vibrational wave is much greater than deviations of the beam, as a result it can be regarded as locally planar. That allows to use a simplified quasi-two dimensional model of interaction between a beam and a gas, according to which the aerodynamic forces acting on each cross-section of the beam can be considered as a result of the planar flow past a section. This model is widely used in many studies [3,10–12]. In particular the suitability of this model was studied by Facci and Porfiri [13]. The authors performed numerical simulation of the 3D flow around the oscillating cantilever beam to investigate the structure of flow and its influence

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